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(54) Method of fabricating a multilayer ceramic substrate.

(57) A method of fabricating a multilayer ceramic substrate with an internal conductive metallurgy circuit network, wherein additional green sheet material (36) is added to the stack (30) of ceramic green sheets during assembly to areas of the substrate outside of the conductive metallurgy to compensate for the volume of conductive metal paste and to thereby eliminate or minimize substrate distortion during the sintering operation.

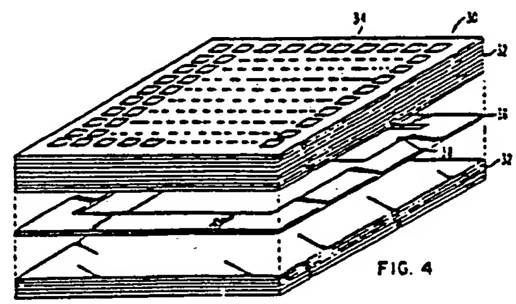


FIG. 4

EP 0 212 124 A1

This invention relates to a method of fabricating a multilayer ceramic substrate with an internal conductive metallurgy circuit network, and more particularly, to a method for eliminating or minimizing distortion of multilayer ceramic substrates used for semiconductor packages.

Because of the high package density attainable with multilayer ceramic (MLC) substrate circuit structure, it has achieved extensive acceptance in the electronics industry for the packaging of integrated circuit semiconductor devices and other elements. In general, such conventional ceramic structures are formed from ceramic green sheets which are prepared from ceramic slurry. The slurry is made by mixing a ceramic particulate, a thermoplastic polymer (e.g. polyvinylbutyral) and solvents for the polymer. This slurry is then cast or doctor bladed into ceramic sheets from which the solvents are subsequently volatilized to provide a coherent and self-supporting flexible green sheet, which may be finally fired to drive off the binder resin and sinter the ceramic particulates together into a densified ceramic unitary substrate.

In the fabrication of multilevel ceramic structure, the green sheets are first punched to form via holes. Subsequently, a pattern of conductive material is deposited in the via holes and on the surfaces of the sheets. The green sheets are then assembled in the proper order and laminated wherein the metallurgy in the via holes and on the green sheets collectively form a complex internal metallurgy network. After the composite substrates have been pressed to adhere the sheets firmly together and indent the conductive metal patterns into the opposed sheets, the substrate is fired in an appropriate atmosphere at a temperature to first burn off the organic binder, and subsequently to sinter the particles of the substrate together to form a unitary ceramic substrate. The original green ceramic sheets are formed on a larger scale so that upon shrinking the spacing of the various elements conforms to the desired standards. The fabrication of multilayer ceramic substrates is described in more detail in U.S. Patent No. 4,245,273. In the manufacture of multilayer ceramic substrates for integrated circuit semiconductor packages, it is imperative that shrinkage that occurs during the sintering operation be predictable and consistent, and also that the shrinkage be uniform throughout the multilayer ceramic substrate. Further, the stresses and material changes generated by the lamination process operate to cause variability during sintering.

An object of this invention is to achieve a shrinkage during sintering of an MLC substrate that is uniform throughout the substrate.

Another object of the invention is to achieve a stable planar sintered substrate free of warpage and where the original geometric shape is retained.

Another object of this invention is to provide a method of producing an MLC substrate that is free of warpage, and where the original geometric shape is retained.

Yet another object of this invention is to provide an intermediate product, i.e. a green ceramic substrate that will have a uniform shrinkage throughout the sub strate, be free of warpage, and retain its original geometric shape during the sintering operation.

The invention as claimed is intended to meet these objectives and to remedy the drawbacks hitherto encountered. In employing the invention the fabrication of multilayer ceramic substrate is improved by adding, during assembly of the stack of ceramic green sheets, additional green sheet material to areas outside that of the conductive metallurgy. The metal volume is thus compensated to provide a more uniform density of the ceramic sheet stack.

The advantages offered by the invention are mainly achieved becaused changes in the geometric shape during substrate sintering are avoided. Since the resulting substrate is substantially free of distortion in the X, Y and Z direction, denser semiconductor device packaging on the substrate and improved testing and cooling feasibility are obtained.

The invention, both as to its modes of practice and organization, together with the further objects and advantages thereof may be best appreciated by reference to the following detailed description taken in conjunction with the drawings wherein

Fig. 1 is a top view of a multilayer ceramic substrate illustrating the shape after sintering in greatly exaggerated dimensions.

Fig. 2 is a side view of the substrate illustrated in Fig. 1, showing the distortion also in exaggerated scale.

Fig. 3 is a side view of a sintered multilayer ceramic substrate formed by the method of the invention illustrating a relatively distortion-free profile shape.

Fig. 4 is a perspective view in exploded relation of a laminated substrate formed of green ceramic sheets illustrating one embodiment of means of compensating with additional ceramic material.

of green ceramic sheets illustrating another embodiment of the invention for compensating with ceramic material.

Fig. 6 is a perspective view of a plurality of green ceramic sheets in exploded relation illustrating yet another preferred specific embodiment of the invention for introducing additional ceramic material to compensate for the metallurgy pattern.

Referring now to the Figures of the drawing, in particular Figs. 1 and 2, there is illustrated the general shape, in greatly exaggerated scale, f a substrate fabricated by techniques conventional in the art. The centrally located green ceramic sheet of a typical MLC substrate has via holes punched, filled with conductive paste, and surface lines formed of conductive material that joins the via. Also, in power planes, an almost solid layer of paste may be deposited on the sheet. These vias and surface patterns are located generally in the central area of the substrate, in general underlying device pads 12 on substrate 10 as shown in Fig. 1. In the border area outside of the device pads 12, there are normally no vias or conductive patterns. When the green ceramic sheets are assembled and laminated, i.e., placed in a press and subjected to pressure, the ceramic material in the centrally located volume of the substrate is compacted to a greater degree than the volume of the substrate without metallurgy, and the density of the ceramic material is greater. While there is some plastic flow of the ceramic material to the volume of the substrate without metallurgy, the flow is not sufficient to equalize the density of the ceramic material. This increased density is not evident in the laminated green ceramic substrate since it conforms to the shape of the press cavity. However, when the substrate is sintered, the geometric shape changes to the shape illustrated in Figs 1 and 2, the sides of the substrate bulge as indicated in exaggerated scale by volumes 14. In addition, the edges become tapered, as indicated in Fig. 2, also in exaggerated scale.

Substrate 10 is thus distorted in the X and Y directions, which complicates placement of devices on pads 12 on the surface pattern. It makes testing the substrate for electrical internal defects difficult since the probes must be placed over and contact the pad pattern. When the top surface metallurgy pattern is distorted, fewer contact points can be made at a time. If the pattern is undistorted, theoretically all the pads could be contacted at once. The greater the distortion the fewer electrical contacts can be made.

As indicated in Fig. 2, the substrate is also distorted in the Z direction. This distortion also complicates testing the substrate for electrical defects. The pads along the edge are lower than the

electrical contact with the outer pad sinc probe will contact the inner pad first and pr the probe from descending to the level of the pads. The seal that ultimately will be establ between the substrate and cap may lso b pacted because of this surface irregularity. further, the top surfaces f the outermost de bonded to the substrate will not be in the plane as the inner devices. When the cond pistons as disclosed in U.S. Patent No. 3.99 are used to cool the devices, the cooling effic is impacted because the piston is tilted relati the surface, thus limiting the area contact.

When the stack of green ceramic shee laminated in a press, the flow of ceramic ma caused by the application of pressure move center layers outwardly. This essentially bow vertical lines of the internal metallurgy outw where the bow is greatest along the outer pe eral areas.

The aforementioned problems become serious as the number of sheets in the sub increase since the complexity f the substra increasing. Due to increased microminiaturiz of the device geometry, the number of sheets substrate will increase which will also increas problems associated therewith.

Fig. 3 illustrates the desired profile of a tered multilayer ceramic substrate 20, which be achieved by this invention. The sub claimed is substantially free of distortion in the and Z directions.

Referring now to Fig. 4 there is illustra first preferred embodiment of the method o invention. Fig. 4 shows an unsintered mult ceramic substrate 30 formed of green ce sheets 32, formed in accordance with known ods. The top sheet has a suitable surface m lurgy pattern 34 (shown schematically) adapt provide electrical connections to a plurality of conductor devices. In order to compensate fo volume of conductive metal paste in the c area of sheets 32, a sheet 36 is disposed i stack of sheets. Sheet 36 is preferably form the same ceramic material as sheet 32, but large central opening 38. Generally, the openi corresponds to the area provided on sheets 3 vias and conduction metallurgy patterns. Thu use of sheet 36 does not require vias or cond patterns to be formed thereon. Any suitable ber of sheets 36 can be placed internally or nally in the stack of sheets 30 in order to min or eliminate density variations in the laminated strate. The sheet 36 can have the same thic as sheets 32 or it can be thicker or thinner dep ing on the need. The number of sheets 36 i

substrate can be determined by trial and error, and is dependent on the nature of the conductive metal paste, the paste thickness and the total number of sheets in the substrate being fabricated.

Referring now to Fig. 5, there is illustrated another embodiment of the invention. Fig. 5 shows a stack 40 of green ceramic sheets 32 formed in accordance with known methods. Sheets 32 have via holes (not shown) filled with conductive metal paste, and metallurgy patterns (not shown) which collectively form an internal metallurgy pattern for an MLC substrate. Inserted in the stack 40 are two sheets 42 with a thinned central portion 44. The sheets 44 are preferably positioned with the direction of casting at right angles to each other. Sheets 42 can be conveniently formed by doctor blading, where the doctor blade is shaped to the compliment of the desired sheet profile. As in the previous method embodiment, the number of sheets inserted in the substrate can vary to meet the individual substrate requirements. Sheets 42 must have via holes punched and filled with conductive metal paste to join the metallurgy patterns on the associated green sheets 32.

Referring now to Fig. 6 of the drawing, there is illustrated yet another embodiment of the invention. Fig. 6 shows a stack 50 of green ceramic sheets 52. Sheets 52 each have a profile designed to compensate for conductive metal paste on the sheets and in the via holes. Here the profiled sheets 52 have via holes (not shown) with conductive metal paste, and conductive lines (not shown) that collectively form an internal metallurgy system. Since the profile variation of sheets 52 vary only slightly from the flat sheets 32 in Figs. 4 and 5, the conventional punching and screening present no significant problem. The stack 50 of green sheets shown in Fig. 6 thus is comprised of uniformly shaped green sheets 52 with a slightly thicker outer profile. As indicated, the direction of casting which corresponds to the profile is varied with each sheet where the direction is advanced 90° relative to the preceding sheet.

In the practice of the invention, any suitable ceramic material combined with an appropriate organic binder and solvent for the binder can be used including alumina ceramic, mullite, glass ceramic, etc. After the stacks of green ceramic sheets have been assembled, they are laminated i.e. pressed between two platens, preferably with a confining edge.

While the invention has been illustrated and described with reference to preferred embodiments thereof, it is to be understood that the invention is not limited to the precise construction herein disclosed and the right is reserved to all changes and modifications coming within the scope of the invention as defined in the appended claims.

Claims

1. A method of fabricating a multi substrate with an internal conductiv circuit network, wherein a slurry of p ramic material, an organic binder and the binder is formed into green cera (32), via holes are punched into the ductive material is deposited in the v on the surface of the sheets to form a ity of green ceramic sheets is assem resultant substrate (30) sintered, char that it comprises the steps of

incorporating additional green ceramic in the substrate during assembly in the erally outside of the areas of conduct lines and filled via holes,

subjecting the resultant substrate to l laminate the sheets, and

sintering the resultant substrate,

said added green ceramic material co for the volume of the conductive mat central portions of said green ceramic sh

2. The method of claim 1, wherein tional green ceramic material is inco said substrate by

forming an opening in the central area one additional green ceramic sheet (36), ing the resultant at least one additional ramic sheet (36) with said plurality of ramic sheets (32) as they are assembled.

. The method of claim 2, wherein sa opening in said at least one additional ramic sheet (36) approximately encompa conductive material lines n the associ plurality of green sheets (32).

4. The method of claim 1, wherein tional green ceramic material is incorp said substrate by

forming at least one additional green cera (42) with a profile having a thinner central

forming via holes in said additional sheet a the via holes with conductive material, and

placing the resultant at least ne addition ceramic sheet (42) with said plurality o ceramic sheets (32) as they are assembled

5. The method of claim 4, wherein h tional green ceramic sheets (42), each wit ner central profile, are placed in the resulta (40) of said plurality of green ceramic she

...ditional green ceramic sheets (42) being ...ped with said profiles orthogonal to each oth-

6. The method of claim 1, wherein said additional green c ramic material is incorporated in said substrate by using a plurality of green ceramic sheets (52) with a sheet profile having a thicker outer section, and wherein said sheets (52) contain via holes filled with conductive material, and lines on the surface, said profile shape of said plurality of green ceramic sheets (52) acting to compensate for the conductive material in the central areas of the sheets.

7. The method of claim 6, wherein said plurality of green ceramic sheets (52) are assembled with said profiles of the sheets arranged orthogonally to the adjacent sheet.

8. An unsintered multiplayer ceramic substrate (30) with an internal conductive metallurgy circuit network, made of green ceramic sheets (32) with via holes and conductive metal lines on the surfaces which collectively form the circuit network, characterized in that it comprises

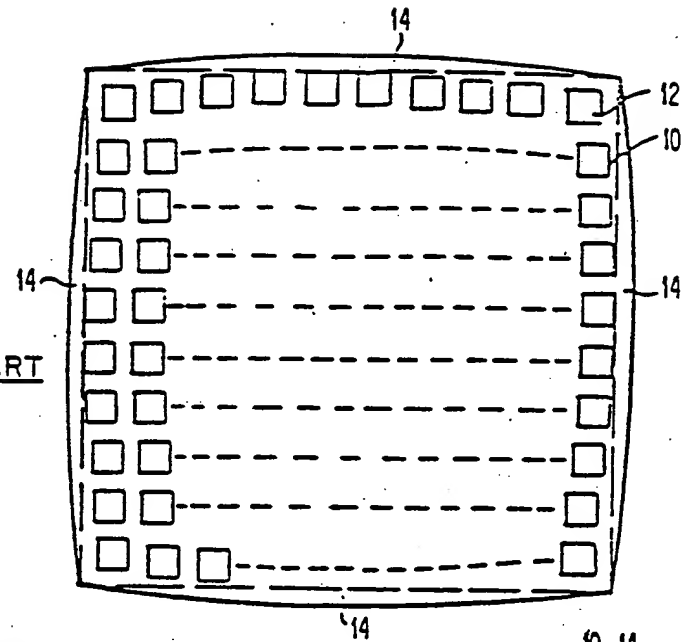
additional green ceramic material in the substrate in areas outside f the areas of the conductive metallurgy network to compensate for the additional volume of material of the conductive metal.

9. The ceramic substrate of claim 8, wherein said additional green ceramic material is in the form of at least one ceramic sheet (36) with a central opening.

10. The ceramic substrate of claim 8, wherein said additional green ceramic material is in the form of at least one green ceramic sheet (42) with a profile having a thinner central portion.

11. The ceramic substrate of claim 8, wherein said additional green ceramic material is provided in that said green ceramic sheets (52) have a profile with a thicker outer portion, said sheets being assembled so that the profiles of the sheets (52) are arranged orthogonal to the adjacent sheet.

PRIOR ART
FIG. 1



PRIOR ART
FIG. 2

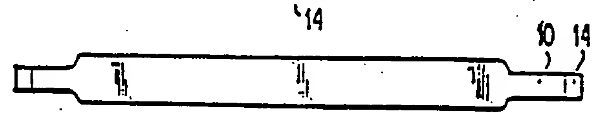
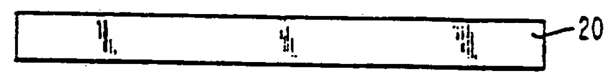


FIG. 3



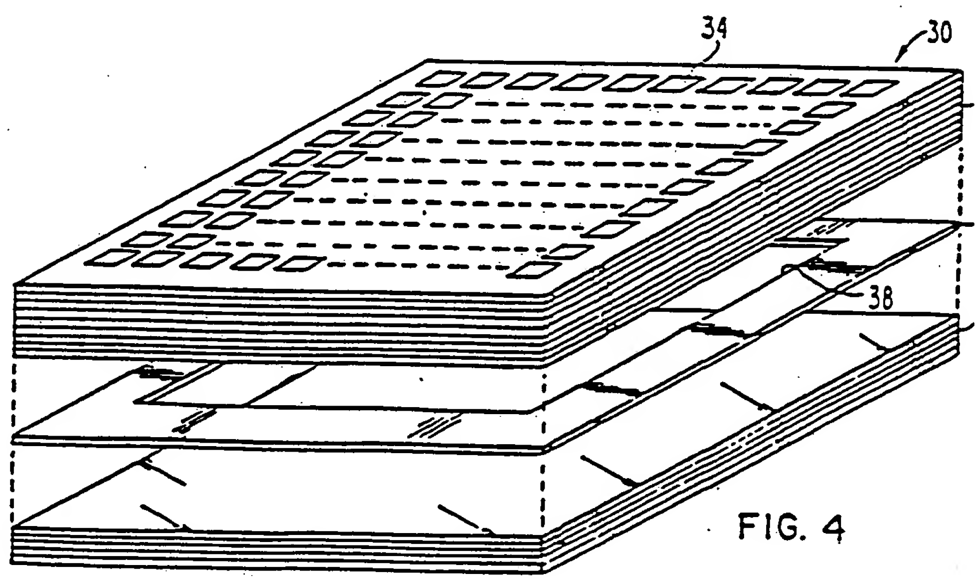


FIG. 4

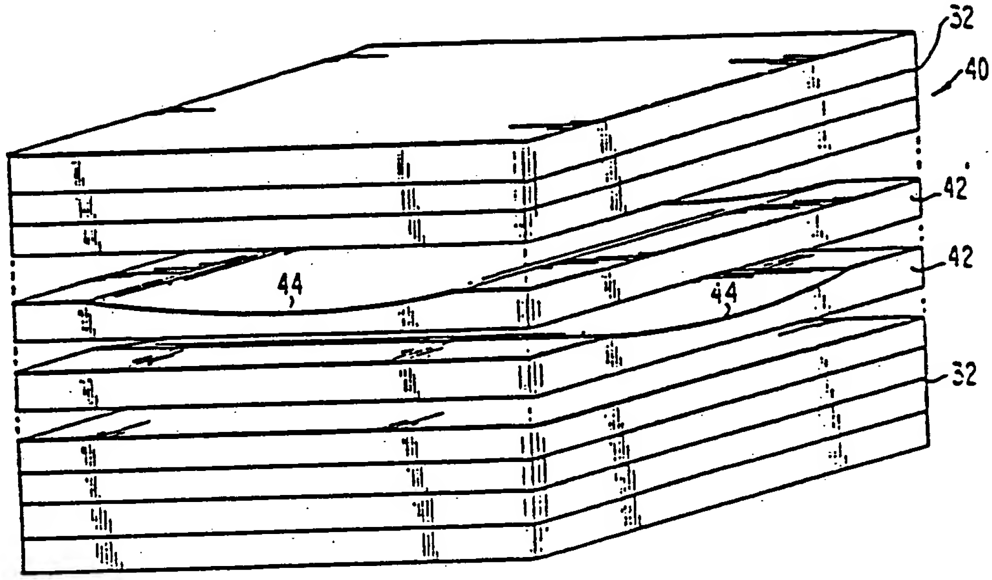


FIG. 5

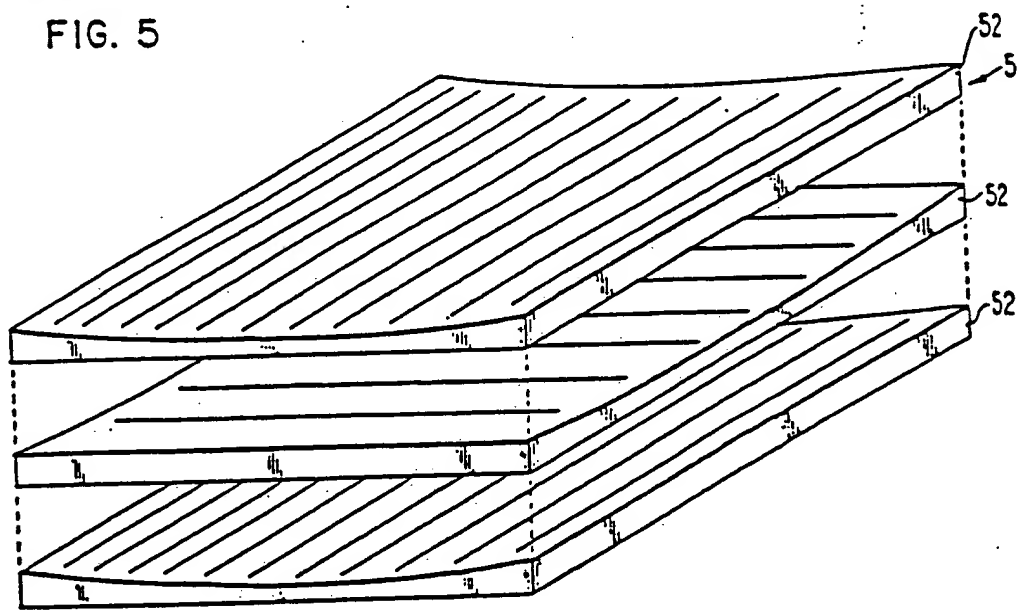


FIG. 6